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A DEVICE AND METHOD FOR ENCODING A DATUM, AND A DEVICE AND METHOD FOR DECODING AN ENCODED DATUM

FIELD OF THE INVENTION

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The present invention relates to a device and method for encoding information (a datum), and a device and method for decoding encoded information. The present invention has particular, but by no means exclusive,

10   application to wireless data communication systems.

BACKGROUND OF THE INVENTION

To facilitate the transfer of a datum such as

15   voice, video or computer data, communication systems convert the datum to/from a predefined format. The function of converting a datum to/from the predefined format is commonly referred to as encoding/decoding. Examples of rudimentary encoding/decoding techniques include amplitude

20   modulation (AM) and frequency modulation (FM).

SUMMARY OF THE INVENTION

According to a first aspect of the present

25   invention, there is provided a device for encoding a datum, the device being operable to encode the datum by effecting a phase difference between one or more first pseudorandom signals and one or more corresponding second pseudorandom signals.

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Encoding signals using pseudorandom codes has the advantage of providing some degree of immunity from interfering signals and noise, this concept being known as process gain. For typical spread-spectrum encoding there

35   must be a tradeoff between the process gain and the data rate. However, one advantage of the present invention is that up to some limit there is no loss of process gain (or

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increase in signal bandwidth) as the data rate increases.
Thus, the device according to the first aspect of the
present invention has the potential to provide a relatively
high spectral efficiency. This is advantageous because it
5   provides for high capacity data transmissions in a limited
bandwidth environment. Using the device according to the
first aspect of the present invention it may be possible to
achieve a spectral efficiency of at least around 2 bits per
second per hertz.
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        Preferably, the device is operable to use any one
of the first pseudorandom signals as a distinct channel
that can be selected to encode the datum.

15   Thus, by treating each of the first pseudorandom
signals as distinct channels the device according to the
first aspect of the present invention is capable of
providing a multiple access scheme capable of supporting
multiple users.
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        Alternatively, the device is operable to use a
plurality of the first pseudorandom signals as a single
channel that can be selected to encode the datum.

25   The advantage of using the plurality of first
pseudorandom signals is that it provides a higher overall
data rate than using just one of the first pseudorandom
signals as a channel.

30   Preferably, the device is operable to effect the
phase difference by controlling a signal generating means,
which is arranged to generate the first pseudorandom
signals, such that it outputs a symbol of each of the first
pseudorandom signals at a predetermined time, wherein the
35   predetermined time results in the phase difference between
the symbol and a corresponding symbol in each of the second
pseudorandom signals.

Thus, the datum is encoded as a phase difference between the first and second pseudorandom signals, where the phase represents the time difference between the epochs

5   of the respective pseudorandom signals.

Preferably, the datum comprises a signal encoded with information.

10   Thus, this effectively allows the device to be used in conjunction with existing data modulation schemes, such as amplitude modulation, phase modulation or quadrative-amplitude modulation. Because the pseudorandom sequence phase is orthogonal to the sequence amplitude and

15   the signal phase, the total data rate can be increased without changing the transmission bandwidth or the spread-spectrum process gain.

Preferably, the first pseudorandom signals and

20   second pseudorandom signals are in the form of direct sequence spread-spectrum signals.

According to a second aspect of the present invention, there is provided a device for decoding an

25   encoded datum, the device being operable to decode the encoded datum by determining a phase difference between one or more first pseudorandom signals and one or more corresponding second pseudorandom signals.

.30   Preferably, the device is operable to use the first pseudorandom signals as a distinct channel that can be selected to decode the datum.

Alternatively, the device is operable to use a

35   plurality of the first pseudorandom signals as a single channel that can be selected to decode the datum.

Preferably, the device is operable to determine the phase difference based on a time difference between a symbol of each of the first pseudorandom signals and a corresponding symbol of each of the second pseudorandom

5 signals, wherein the time difference is representative of the phase difference.

Preferably, the datum comprises a signal encoded with information.

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Preferably, the first pseudorandom signals and second pseudorandom signals are in the form of direct sequence spread-spectrum signals.

15   According to a third aspect of the present invention, there is provided a method of encoding a datum, the method comprising the step of encoding the datum by effecting a phase difference between one or more first pseudorandom signals and one or more corresponding second

20 pseudorandom signals.

Preferably, the step of encoding the datum comprises the step of using any one of the first pseudorandom signals as a distinct channel that can be

25 selected to encode the datum.

Alternatively, the step of encoding the datum comprises using a plurality of first pseudorandom signals as a single channel that can be selected to encode the

30 datum.

Preferably, the step of encoding the datum is such that the phase difference is effected by controlling a signal generating means, which is arranged to generate the

35 first pseudorandom signals, such that it outputs a symbol of each of the first pseudorandom signals at a predetermined time, wherein the predetermined time results

in the phase difference between the symbol and a
corresponding symbol in each of the second pseudorandom
signals.

5   Preferably, the datum comprises a signal encoded
with information.

           Preferably, the first pseudorandom signals and
second pseudorandom signals are in the form of direct
10   sequence spread-spectrum signals.

           According to a fourth aspect of the present
invention, there is provided a method of decoding an
encoded datum, the method comprising the step of decoding
15   the encoded datum by determining a phase difference between
one or more first pseudorandom signals and one or more
corresponding second pseudorandom signals.

           Preferably, the step of decoding the encoded
20   datum comprises the step of using any one of the first
pseudorandom signals as a separate channel that can be
selected to decode the datum.

           Alternatively, the step of decoding the encoded
25   datum comprises the step of using a plurality of the first
pseudorandom signals as a single channel that can be
selected to decode the datum.

           Preferably, the step of decoding the encoded
30   datum is such that the phase difference is determined by a
time difference between a symbol of each of the first
pseudorandom signals and a corresponding symbol of each of
the second pseudorandom signals, wherein the time
difference is representative of the phase difference.

35
           Preferably, the datum comprises a signal encoded
with information.

Preferably, the first pseudorandom signals and second pseudorandom signals are in the form of direct sequence spread-spectrum signals.

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According to a fifth aspect of the present invention there is provided software, which when executed by a computing device, enables the computing device to carry out the method as described in the paragraphs

10   referring to the third or fourth aspects of the invention.

According to a sixth aspect of the present invention there is provided a computer readable medium comprising the software described in the paragraph

15   referring to the fifth aspect of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Notwithstanding any other embodiments that may

20   fall within the scope of the present invention, an embodiment of the present invention will now be described, by way of example only, with reference to the accompanying figures, in which:

25   figure 1 provides an illustration of a block diagram of the preferred embodiment of a device for encoding a datum;

figure 2 provides an illustration of a

30   representation of a pseudo-noise sequence generated by the device shown in figure 1;

figure 3 provides an illustration of a block diagram of a pseudo-noise sequence generator used in the

35   device of figure 1; and

figure 4 provides an illustration of a block

diagram of the preferred embodiment of a device for
decoding a datum that has been encoded using the device
shown in figure 1; and

5   figure 5 provides an illustration of a
correlogram showing the correlation relationship between
signal strength and phase difference (correlation time) of
two bandlimited pseudorandom signals;

10   figure 6 provides a flow chart of the steps
performed by the device of figure 1;

            figure 7 provides a flow chart of the steps
performed by the device of figure 4;

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            figure 8 provides an illustration of the use of
channels by the device of figure 1; and

            figure 9 provides another illustration of the use
20 of channels by the device of figure 1.

AN EMBODIMENT OF THE INVENTION

            As can be seen in figure 1, an embodiment of the
25 device 1 for encoding a datum comprises a controller 3, a
pseudorandom sequence generator 5, a lowpass filter 7, a
modulation circuit 9, and an oscillator 11.

            The controller 3 is in the form of a digital
30 integrated circuit that has an input port 13 for receiving
the datum 15 that is to be encoded. The datum 15 is in the
form of a series of binary bits that are representative of,
for example, voice or computer data. It is also envisaged
that the datum 15 could be in the form of a signal that is
35 encoded with information. For example, the signal could be
encoded using existing modulation techniques such as
amplitude modulation, phase modulation or quadrative-

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amplitude modulation. Where the series of binary bits
forming the datum 15 are representative of analogue
information (such as voice), the analogue information is
converted to the series of binary bits by an analogue to
5   digital converter (not shown in the figures).

The controller 3 is such that it is configured to
process the datum 15 and create a control signal that is
unique to the sequence of binary bits that form the datum
10   15. The control signal is also in the form of binary data.
The controller 3 forwards the control signal to the
pseudorandom sequence generator 5 via an output port 17,
which is connected to an input port 19 of the pseudorandom
generator 5.

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The pseudorandom sequence generator 5, which is
in the form of a digital integrated circuit, generates one
or more first pseudorandom sequences that, as discussed
shortly, are used to encode the datum 15. Each
20   pseudorandom sequence is orthogonal to any other
pseudorandom sequence created by the pseudorandom sequence
generator 5. An example of a pseudorandom sequence is shown
in figure 2.

25   The pseudorandom sequences are generated by using
a read-only memory (ROM), the size of which is related to
the number of pseudorandom sequences and the length of the
sequences. Each pseudorandom sequence has a start address
in the ROM, so the input data on port 19 can be converted
30   to an appropriate ROM address. In the case where the
pseudorandom sequences are simply a shifted version of one
another, the input data can be converted into a ROM address
plus an offset, with the address wrapping around when the
end of the sequence is reached.

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It will be appreciated that other techniques can
be used to generate the pseudorandom sequences. One such

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technique that may be to employ shift registers with a
number of feedback paths. A block diagram of the digital
logic used in each of the shift registers is shown in
figure 3. Each feedback shift register includes consecutive
5   stages of two-state memory devices 21 and feedback logic
23, which is in the form of exclusive-OR gates.

        The pattern of the feedback paths determine the
pseudorandom sequences produced, while the initial pattern
10 in the shift register determines the starting bit of the
pseudorandom sequences. Configuring the feedback shift
registers to generate pseudorandom sequences is achieved by
loading the memory devices 21 with an appropriate binary
sequence. Alternatively, multiple shift registers can be
15 used to generate each sequence required. If the
pseudorandom sequences are based on a maximum-length
sequence, then the sequences will have good cross-
correlation properties when correlated with a shifted
version of itself, and thus the sequences are essentially
20 orthogonal to each other.

        In order to encode the datum 15, the pseudorandom
sequence generator 5 commences 'clocking-out' (outputting)
each of the pseudorandom sequences from a specific point
25 (bit) of each of the pseudorandom sequences. For example,
if the binary bits forming the datum 15 were 1010, the
pseudorandom sequence generator 5 could commence clocking-
out of the pseudorandom sequence from section "A" (see
figure 2). On the other hand, if the datum 15 consisted of
30 0011, the pseudorandom sequence generator 5 could commence
clocking-out of the pseudorandom sequence from section "B"
(see figure 2).

        As will be discussed shortly, the section from
35 which clocking-out of each of the first pseudorandom
sequences commences effects a phase difference between the
first pseudorandom sequences and the second pseudorandom

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sequences, the phase difference being representative of the encoded datum 15.

The point from which clocking-out of the first
5   pseudorandom sequences commences is actually controlled by the control signal that is created by the controller 3, which as discussed previously, is fed to the pseudorandom sequence generator 5. Upon receiving the control signal, the pseudorandom sequence generator 5 uses the control
10   signal to determine the sections of the first pseudorandom sequences from which clocking-out is to commence.

Once the first pseudorandom sequences have been generated, the pseudorandom sequence generator 5 forwards
15   the first pseudorandom sequences to an output port 25, which is connected to an input port 27 of the lowpass filter 7. The first pseudorandom sequences pass through the filter 7, which removes unwanted high frequency components from the first pseudorandom sequences. The filtered first
20   pseudorandom sequences are then passed to the modulation circuit 9 via an output port 29 of the lowpass filter 7, which is connected to an input port 31 of the modulation circuit 9. The lowpass filter 7 is in the form of a digital filter that is implemented in hardware (digital integrated
25   circuit). It will be appreciated, however, that an analogue filter could be used in an alternative embodiment of the present invention.

In addition to the filtered first pseudorandom
30   sequences, the modulation circuit 9 receives a separate radio frequency signal for each filtered first pseudorandom sequence from the oscillator 11. The modulation circuit 9 uses the filtered first pseudorandom sequences to modulate the corresponding radio frequency signals (received from
35   the oscillator 11) using binary RF phase modulation to produce a number of spread-spectrum signals.

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The device 1 transmits the spread-spectrum signals to a receiver. Whilst not shown in the figures, the device 1 comprises circuitry that is arranged to process the spread-spectrum signals (for example, amplification)
5   before they are transmitted to the receiver. The processed spread-spectrum signals are fed to an antenna so that they can be transmitted to the receiver.

The device 1 is arranged to either use each of
10   the first pseudorandom sequences as distinct channels that can be used to encode the datum 15, or use a plurality of the first pseudorandom sequences as a single channel for encoding the datum 15. In this regard, figure 8 provides an illustration of the concept of using a single channel for a
15   user (multiple access scheme), whilst figure 9 provides an illustration of the concept of using multiple channels for a single user.

To decode the datum 15 from the spread-spectrum
20   signals transmitted by the device 1, the receiver comprises a device 33 illustrated in figure 4. The device 33 comprises an RF bandpass filter 35, a demodulator 37, a pseudorandom sequence generator 39, and a controller 41.

25   Although not illustrated, the device 33 also comprises receiver circuitry that carries out initial processing of the received spread-spectrum signals (for example, amplification). Once the initial processing of the spread-spectrum signals has been carried out, the receiver
30   circuitry forwards the spread-spectrum signals to the lowpass filter 35 so that unwanted components can be removed from the spread-spectrum signals. The filtered spread-spectrum signals are fed to an output port 43 of the filter 35. The output port 43 is connected to an input port
35   45 of the demodulator 37 so that the filtered spread-spectrum signals are passed to the demodulator 37. The filter 35 is a digital filter implemented in hardware.

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However, it will be appreciated that an analogue filter
could be used in an alternative embodiment of the present
invention.

5   In addition to receiving the filtered spread-
spectrum signals, the demodulator 37, which is in the form
of a suitably programmed digital signal processor, also
receives second pseudorandom sequences from the
pseudorandom sequence generator 39. The pseudorandom
10   sequence generator 39 generates the second pseudorandom
sequences using feedback shift registers that are the same
as those used in the pseudorandom sequence generator 5.

         Each of the second pseudorandom sequences
15   received by the demodulator 37 corresponds to one of the
received spread-spectrum signals. The second pseudorandom
sequences generated by the pseudorandom sequence generator
39 are the same as the pseudorandom sequences generated by
the pseudorandom sequence generator 5. The demodulator 37
20   multiplies each of the filtered spread-spectrum signals by
the second pseudorandom sequence that corresponds thereto.
The multiplication process extracts a number of signals
from the filtered spread-spectrum signals. The process of
multiplication and integrating over a period equal to the
25   length of the code effectively generates the cross-
correlation between the transmitted sequences and the
second sequence in the receiver.

         The output of the correlator has a strength
30   (amplitude) that is dependant on the code phase difference
between the received spread-spectrum signals and the
corresponding second pseudorandom sequence generated by the
pseudorandom sequence generator 39. The relationship
between the code phase difference and the signal strength
35   is represented in the correlogram shown in figure 5.

         The demodulator 37 is arranged to create

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information that is indicative of the strength of each of
the signals that are extracted by the multiplication and
integration process. The demodulator 37 places the
information on output port 47 of the demodulator 37 so that
5   it can be passed to the controller 41 via an input port 49
thereof, which is connected to the output 47 of the
demodulator 37.

        The controller 41, which is in the form of a
10   suitably programmed microprocessor, is arranged to decode
the encoded datum 15 by determining a phase difference
between the spread-spectrum signals received by the
demodulator 37 and the corresponding second pseudorandom
sequences generated by the generator 39. The phase
15   difference is such that it corresponds to a maximum
strength of the signals extracted by the correlation
process. An example of the correlation output as a function
of correlation time (phase) is shown in figure 5. The width
of the correlation pulse is about twice the chip period of
20   the pseudorandom signal.

        To determine the phase difference, the controller
41 processes the information received via the input port 49
so as to determine the strength of the signals extracted by
25   the correlation process. While monitoring the strength of
the signals, the controller 41 controls the pseudorandom
sequence generator 39 such that the second pseudorandom
sequences generated thereby are 'shifted' in time to a
point where the strength of the signals are at a peak. The
30   controller 41 measures the amount of the shift in time of
the second pseudorandom sequences that results in the
signals having a peak signal strength. The amount of shift
in time required to produce the peak signal strength is
effectively equivalent to the phase difference created by
35   the transmitter device 1.

        Once the phase difference has been determined,

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the controller 41 essentially refers to a form of look up
table to determine a binary sequence which corresponds to
the phase difference. The corresponding binary sequence
being the same as the datum 15 encoded by the device 1.

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   In order to shift the second pseudorandom
sequences in time, the controller and the pseudorandom
sequence generator 39 use the same clocking out technique
as employed by the controller 3 and the pseudorandom

10   sequence generator 5.

   The various steps carried out to encode the datum
15 are shown in the flow chart of figure 6, whilst the
steps performed to decode the datum are shown in the flow

15   chart of figure 7.

   It will be appreciated that whilst the
description of the embodiment refers to the use of hardware
to implement the various functionality associated with the

20   present invention, it is possible to use other embodiments
in which the functionality is embodied in software for use
with suitable hardware.

   It is noted that the word "phase" throughout the

25   present specification is considered to have its ordinary
meaning of: the relationship in time between the cycles of
an oscillating or repeating system and a fixed reference
point or a different system.

30   Those skilled in the art will operate that the
invention described herein is susceptible to variations and
modifications other than those specifically described. It
should be understood that the invention comprises all such
variations and modifications that fall within the spirit

35   and scope of the invention.